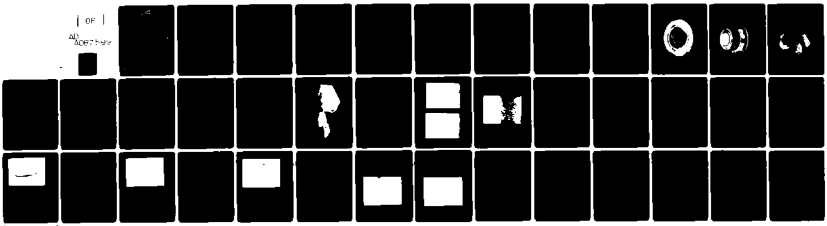
AD-A087 599 MARTIN MARIETTA AEROSPACE DENVER CO DENVER DIV F/G 17/5
BREADBOARD UV PHOTON DETECTION SYSTEM.(U)
JUL 80 J G MCCOY DAAK20-79-C-0501
UNCLASSIFIED NL

1 OF 1
AD A087599



END
DATE FILMED
9-80
DTIC

LEVEL II

12

Report DAAK20-79-C-0501-001

BREADBOARD UV PHOTON DETECTION SYSTEM

ADA087599

John G. McCoy
Martin Marietta Aerospace
P.O. Box 179
Denver, Colorado 80201

DTIC
ELECTE
AUG 7 1980
S C

July 1980

Final Report, Contract DAAK20-79-C-0501

Approved for public release; distribution unlimited.

Prepared for:
US ARMY ELECTRONICS RESEARCH AND DEVELOPMENT COMMAND
Ft. Monmouth, N.J. 07703

DDC FILE COPY

80 8 7 047

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DAAK20-79-C-0501-001	2. GOVT ACCESSION NO. AD-A087599	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Breadboard UV Photon Detection System		5. TYPE OF REPORT & PERIOD COVERED Final Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) John G. McCoy		8. CONTRACT OR GRANT NUMBER(s) DAAK20-79-C-0501
9. PERFORMING ORGANIZATION NAME AND ADDRESS Martin Marietta Aerospace P.O. Box 179, Denver, CO 80201		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1L1 62715 A042 0309
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Electronics Research & Development Cmd, Ft. Monmouth, N.J. 07003		12. REPORT DATE July 1980
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Digicon, Ultraviolet detectors, Electro-optics, Photon counting detector.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A prototype UV digicon-type detector is being developed for possible military application. The system has been breadboarded for demonstration and evaluation purposes. This four channel breadboard system consisting of a digicon detector, power supply, and data handling electronics is described. Results of testing are also presented and discussed.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

405555

FOREWORD

This is the final report of work on the development of a Breadboard UV Photon Detection System under contract to the US Army Electronics Research and Development Command, Ft. Monmouth, N.J. on DA Project 1L1 62715 A042. Comments, criticisms, or questions concerning this report may be addressed to: Commander, US Army Electronic Warfare Laboratory, ERADCOM, ATTN: DELEW-E (J. Charlton), Ft. Monmouth, N.J. 07703, Telephone: (201) 544-4019.

Accession For	
NTIS GRA&I	☑
DDC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or special
A	

CONTENTS

FIGURES

TABLES

1. INTRODUCTION

The proximity focused ultraviolet digicon tube (Ref. 1) is a small, lightweight, rugged, sensitive UV detector having the potential of satisfying a number of military requirements. The purpose of this program has been to design, fabricate and test a breadboard single channel TTL-compatible ultraviolet photon detection system using a UV digicon as the photon sensor and to obtain performance characteristics from this system. These data will be used to provide a first assessment of the potential of digicon detectors for use in passive UV threat warning systems.

2. DISCUSSION

2.1 System design

The breadboard ultraviolet photon detector system consisting of a digicon sensor, high voltage power supply and filter, and signal processing electronics is illustrated in Figure 1. The sensor (Figure 2) is a multi-element digicon based on a design developed for the Air Force Geophysics Laboratory's Multi Spectral Measurements Program (MSMP). The digicon basically consists of a sapphire window with semi-transparent photocathode, a ceramic body and a silicon diode detector array. Electrons liberated from the photocathode by ultraviolet photons are accelerated towards the diode detector under the influence of a static electric field, and lose their energy on striking the silicon diode detector creating electron-hole pairs in the semiconductor material. On the average, one electron-hole pair is generated for each 3.6 eV of energy loss. Energies of between 20 keV and 25 keV are required to produce charge pulses of sufficient amplitude for clean signal-to-noise discrimination.

The detailed design of the digicon tube, driven by the fabrication sequence and the need to stand off 25 kV has remained unchanged from earlier digicons. Since spatial resolution is not required for this application and maximum photometric sensitivity is required, the 10 x 10 diode matrix used in the MSMP imaging detector was replaced with a large area solid state detector. This detector was made from high resistive (9-20,000 Ω/cm) N on P silicon in

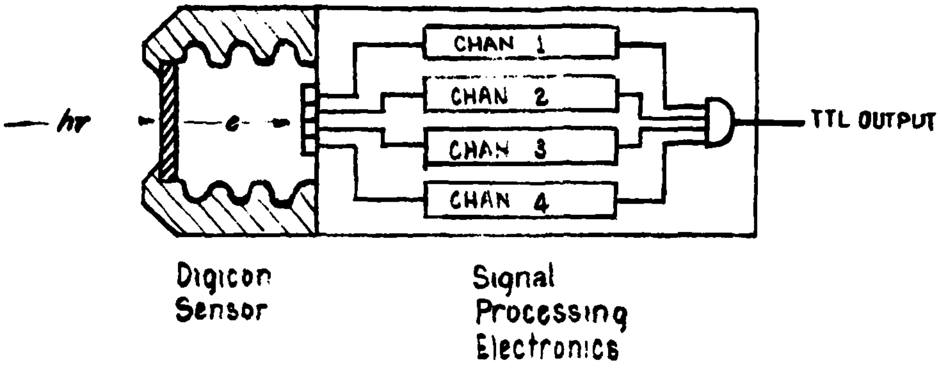


Figure 1. Block Diagram, Breadboard UV Photon Detection System

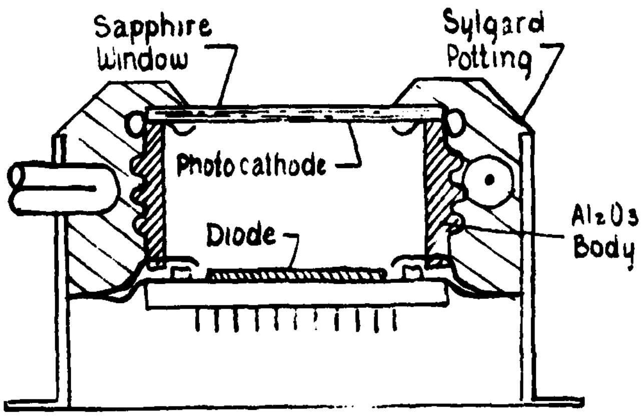


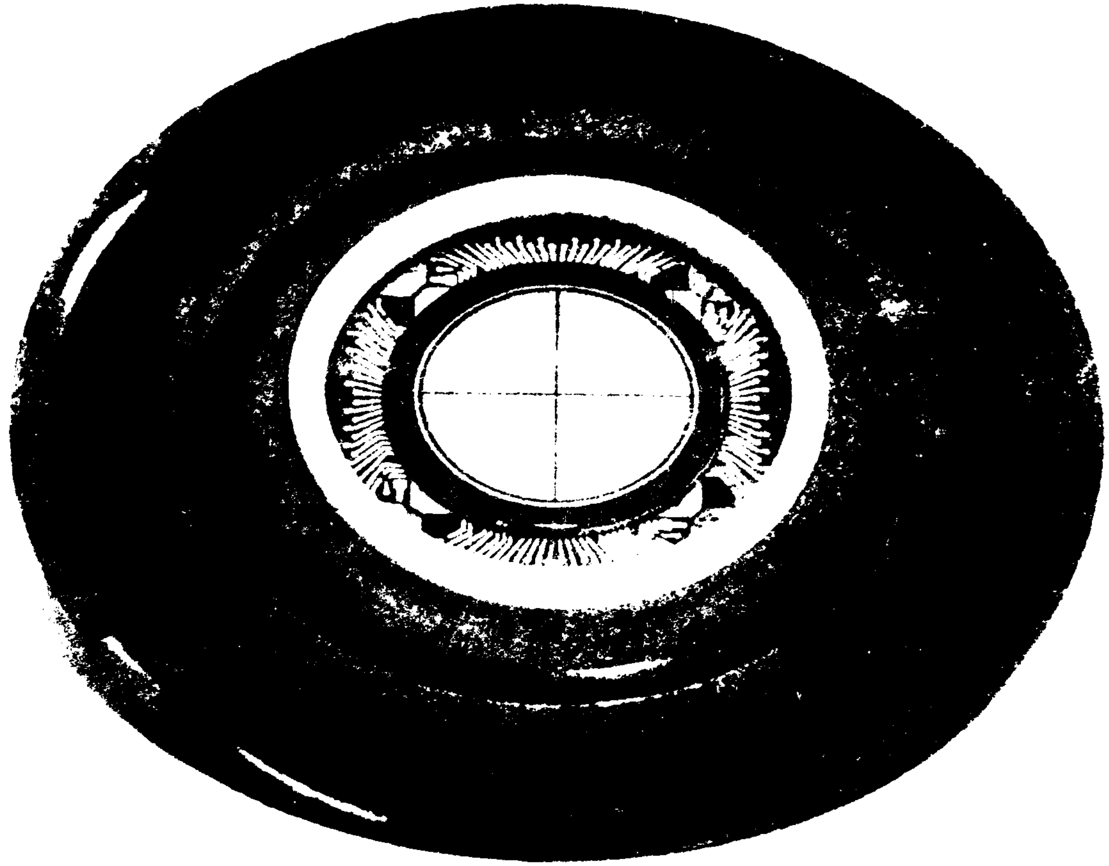
Figure 2. Digicon Detector Tube Assembly

the form of a 15.875 mm dia disk divided into quadrants surrounded by a guard ring (Figure 3). The silicon was overcoated with aluminum for protection and light opacity and then bonded and wired to the digicon header. The header was then TIG welded to the digicon body flange. Final fabrication of the tube was made in a vacuum chamber at approximately 10^{-9} torr. The cesium telluride photocathode was deposited on the sapphire window and the window then sealed to the digicon body using molten indium (Figure 4). After preliminary checkout the digicon was potted in its housing using Silgard 184 for high voltage insulation. (Figure 5)

The charges deposited in the silicon diode detectors are fed into charge sensitive amplifiers, the first stages of the signal processing electronics (Figure 6). The resulting pulses are shaped and amplified for level discrimination. The output of the level discriminator, which is set to pass pulses equivalent to the 25 keV electron events and discriminate against amplifier noise, triggers a one shot which is "OR'ed" with the output of the other three channels' one shots to provide the serial pulse stream for the TTL interface. A schematic of the signal processing electronics is presented in Figure 7.

High voltage for electron acceleration is provided by a Spellman FRM25N1500 High Voltage Power Supply followed by an RCRC filter. This power supply is capable of providing 25 kV at 50 μA.

The completed Breadboard UV Photon Detector System is illustrated in Figure 8.



Figure

Quadrant Diode Array
in Header

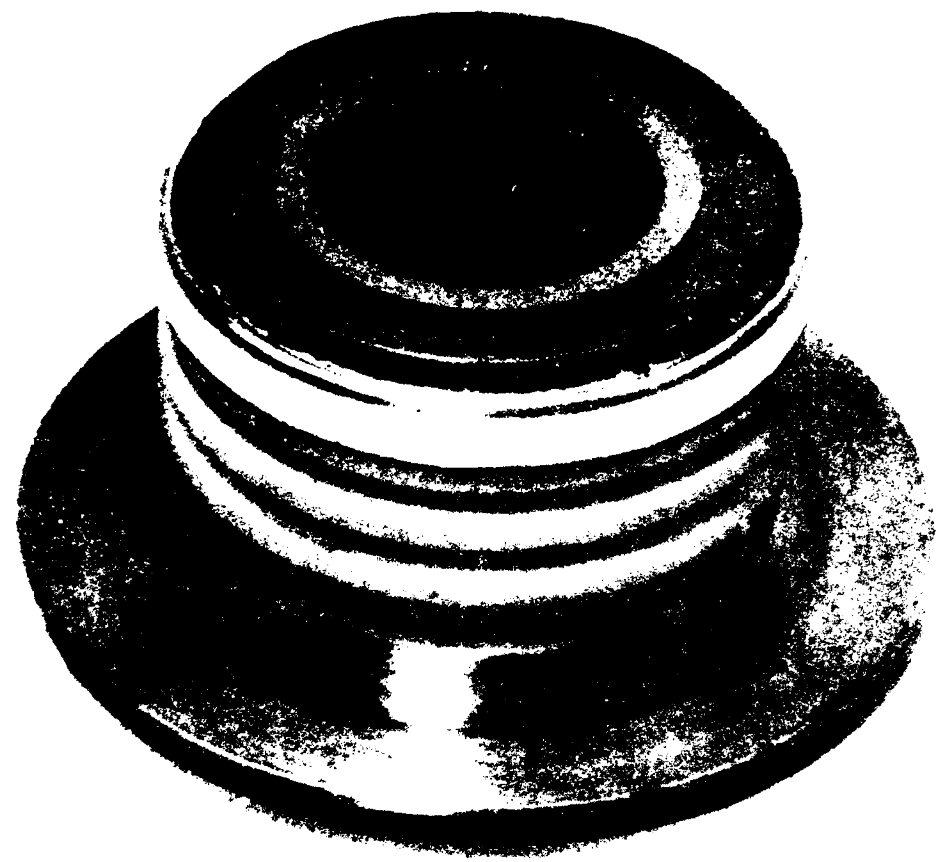


Figure 4

Ultraviolet Digicon (Unpotted)

Figure [illegible]

Ultraviolet Vidicon (Potted)

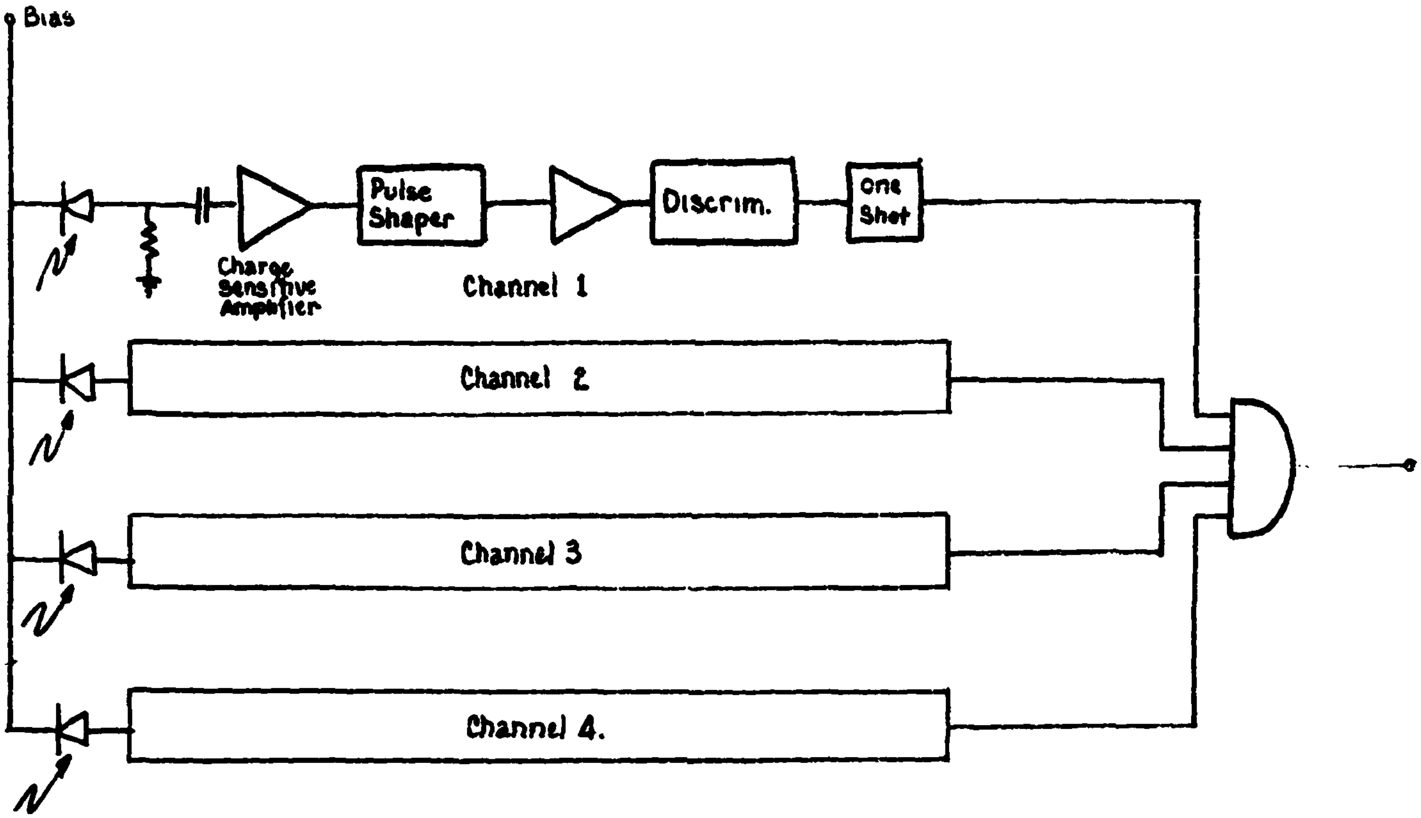
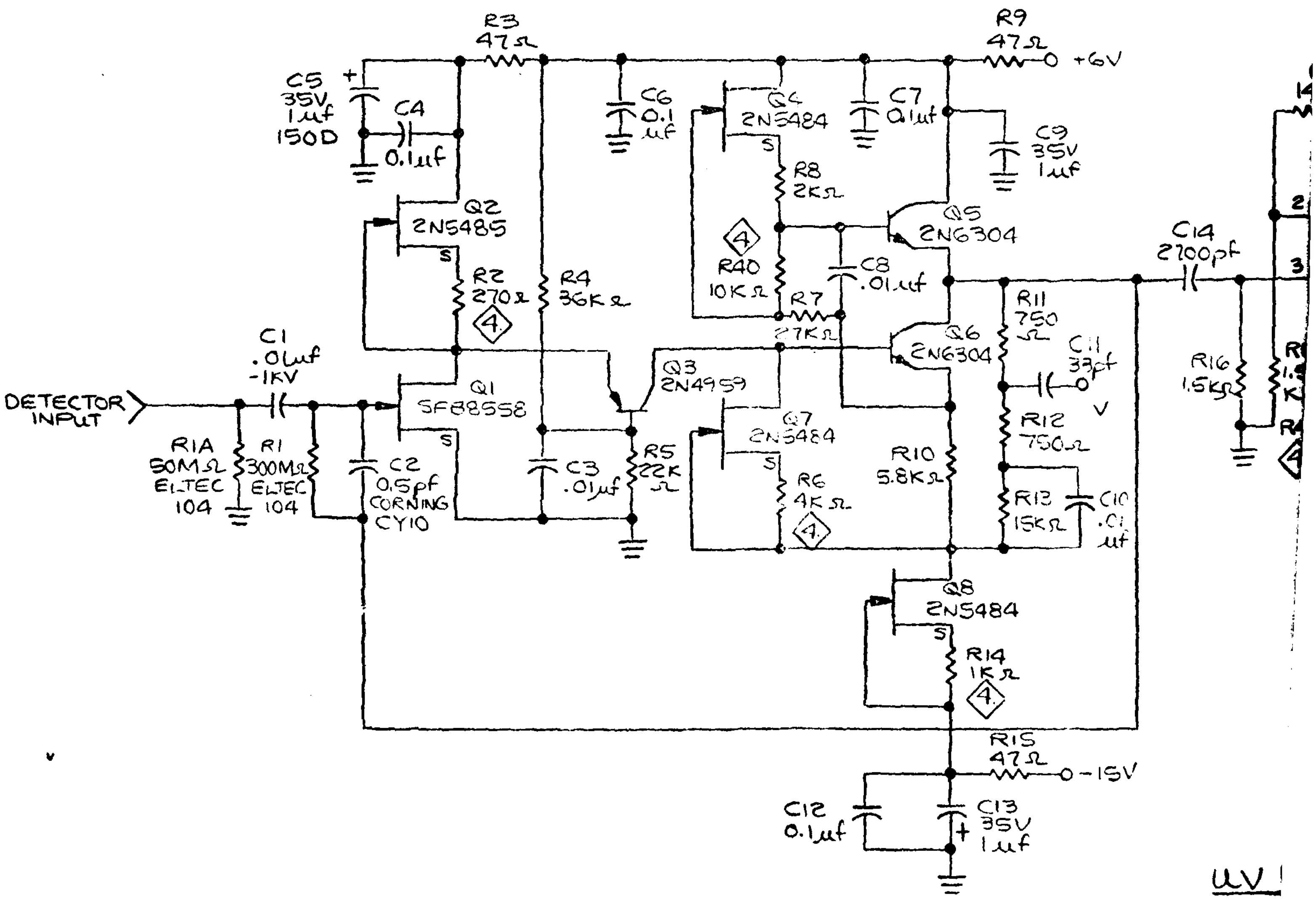
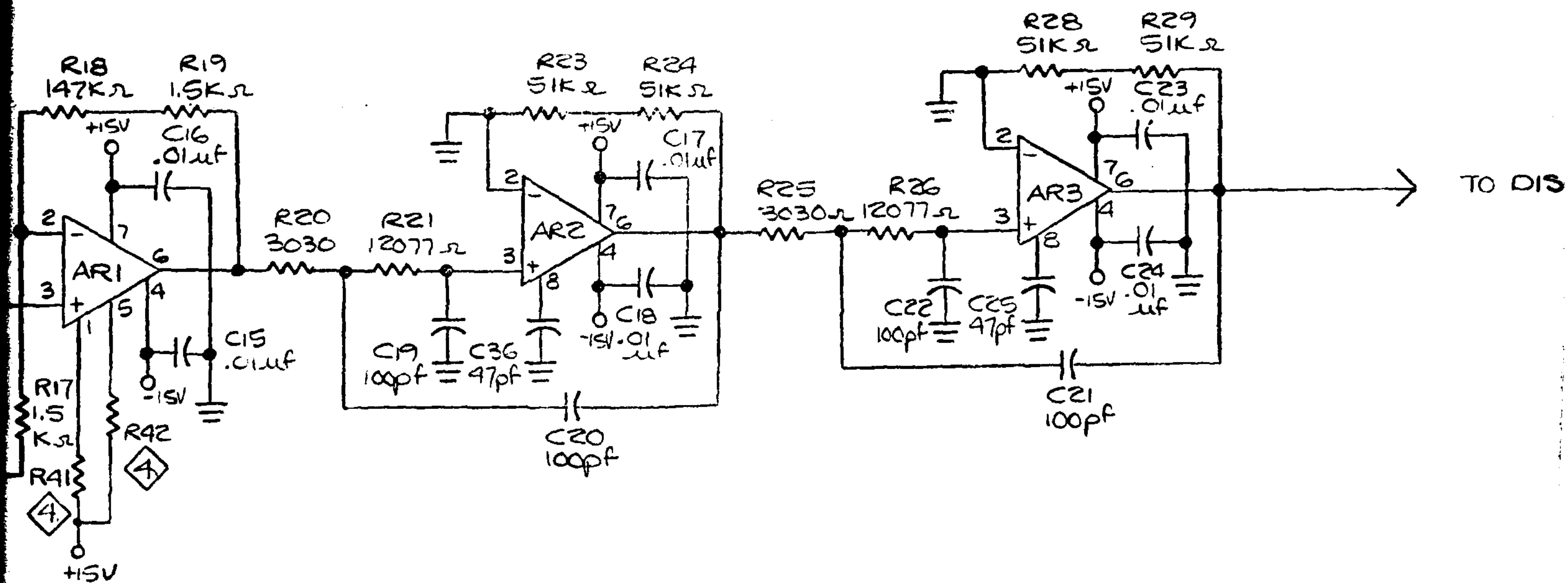


Figure 6

Block Diagram
Signal Processing Electronics



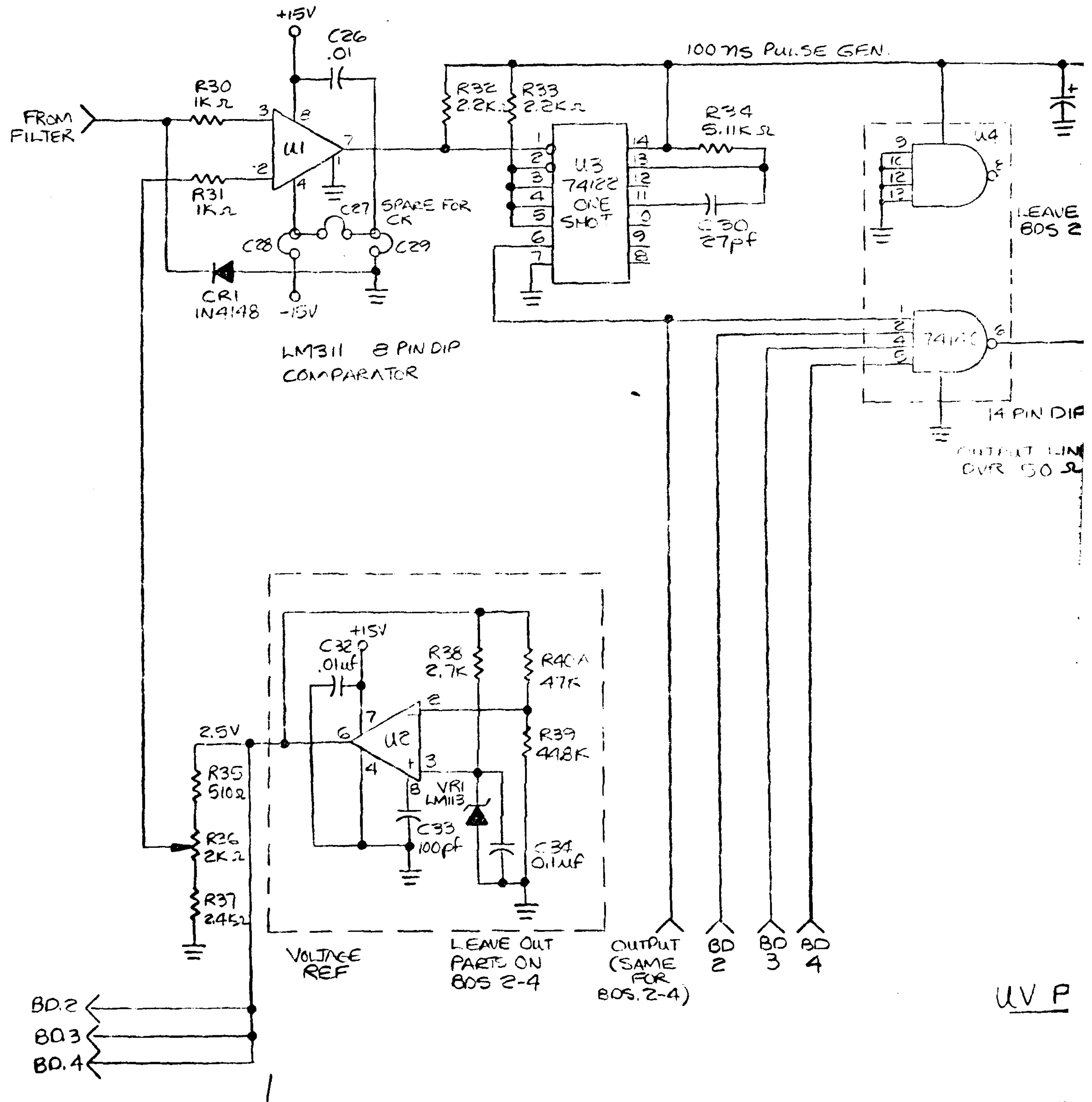
R3 47Ω
R9 47Ω
+6V
C5 35V 1μf 150D
C4 0.1μf
C6 0.1 μf
Q4 2N5484
C7 0.1μf
C9 35V 1μf
R8 2KΩ
Q2 2N5485
Q5 2N6304
C14 2700pf
R40 10KΩ
C8 .01μf
R2 270Ω
R4 36KΩ
R7 27KΩ
R11 750Ω
Q6 2N6304
C1 .01μf -1KV
C11 33pf
Q3 2N4959
R16 1.5KΩ
DETECTOR INPUT
Q1 SF88558
Q7 2N5484
R12 750Ω
R1A 50MΩ ELTEC 104
R1 300MΩ ELTEC 104
C2 0.5pf CORNING CY10
C3 .01μf
R5 22K Ω
R10 5.8KΩ
R6 4K Ω
R13 15KΩ
C10 .01 μf
Q8 2N5484
R14 1KΩ
R15 47Ω
-15V
C12 0.1μf
C13 35V 1μf



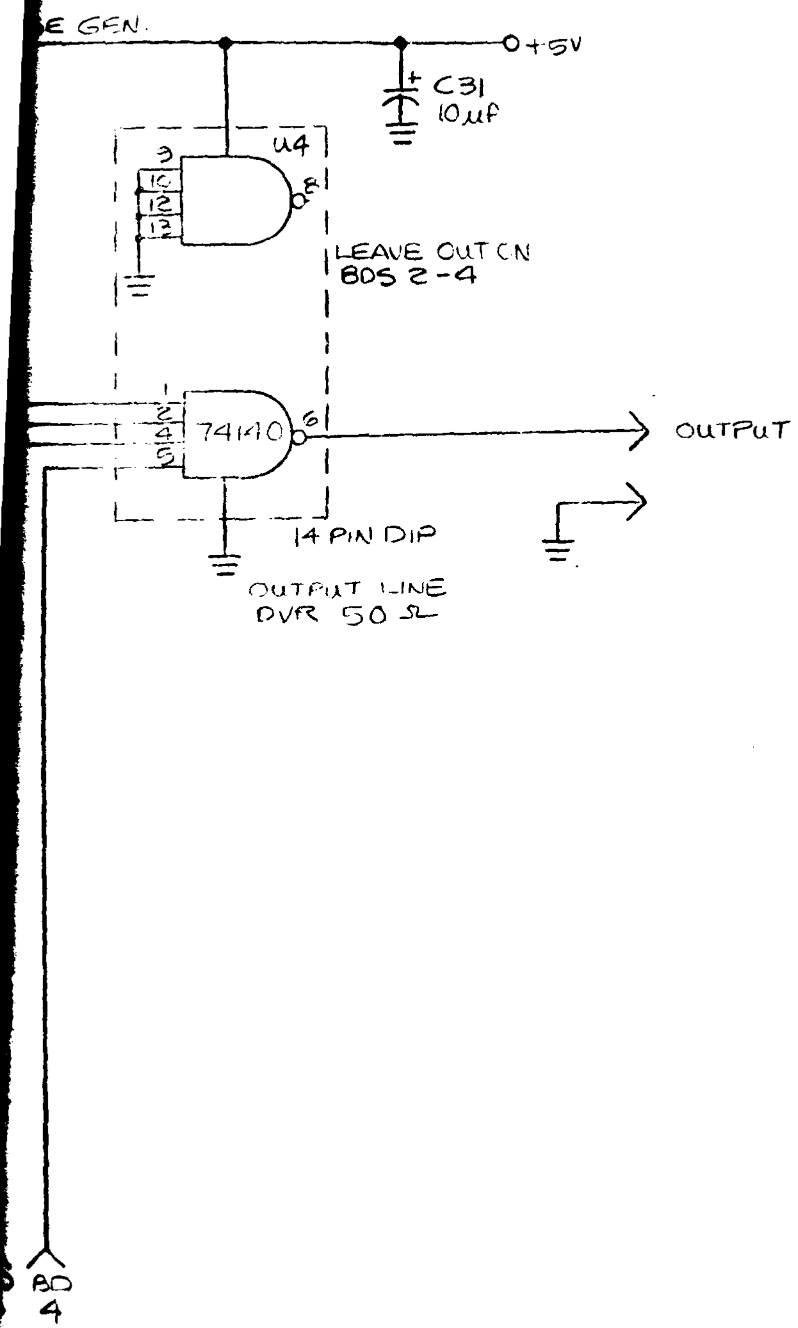
NOTES: (UNLESS OTHERWISE SPECIFIED)
1. ALL AMPLIFIERS ARE HA2-2620 - TO-99
2. ALL RESISTORS ARE RLR05
3. ALL CAPACITORS ARE CKR06
4. SELECT IN TEST.

/ PHOTON COUNTER

2



+15V
C26
.01
100 ns PULSE GEN.
R30
1K Ω
FROM FILTER
U1
R31
1K Ω
R32
2.2K
R33
2.2K Ω
R34
5.11K Ω
U3
74122
ONE SHOT
C30
27pf
U4
SPARE FOR CK
C27
C28
C29
CR1
1N4148
-15V
LM311 8 PIN DIP
COMPARATOR
LEAVE
BDS 2
74
14 PIN DIP
OVR 50 Ω
+15V
C32
.01uf
R38
2.7K
R40A
47K
R39
44.8K
U2
2.5V
R35
510Ω
R36
2K Ω
R37
2.45Ω
VR1
LM113
C33
100pf
C34
0.1uf
VOLTAGE REF
LEAVE OUT PARTS ON BDS 2-4
OUTPUT (SAME FOR BDS. 2-4)
BD 2
BD 3
BD 4
BD.2
BD.3
BD.4
UV P



UV PHOTON COUNTER (a)

2

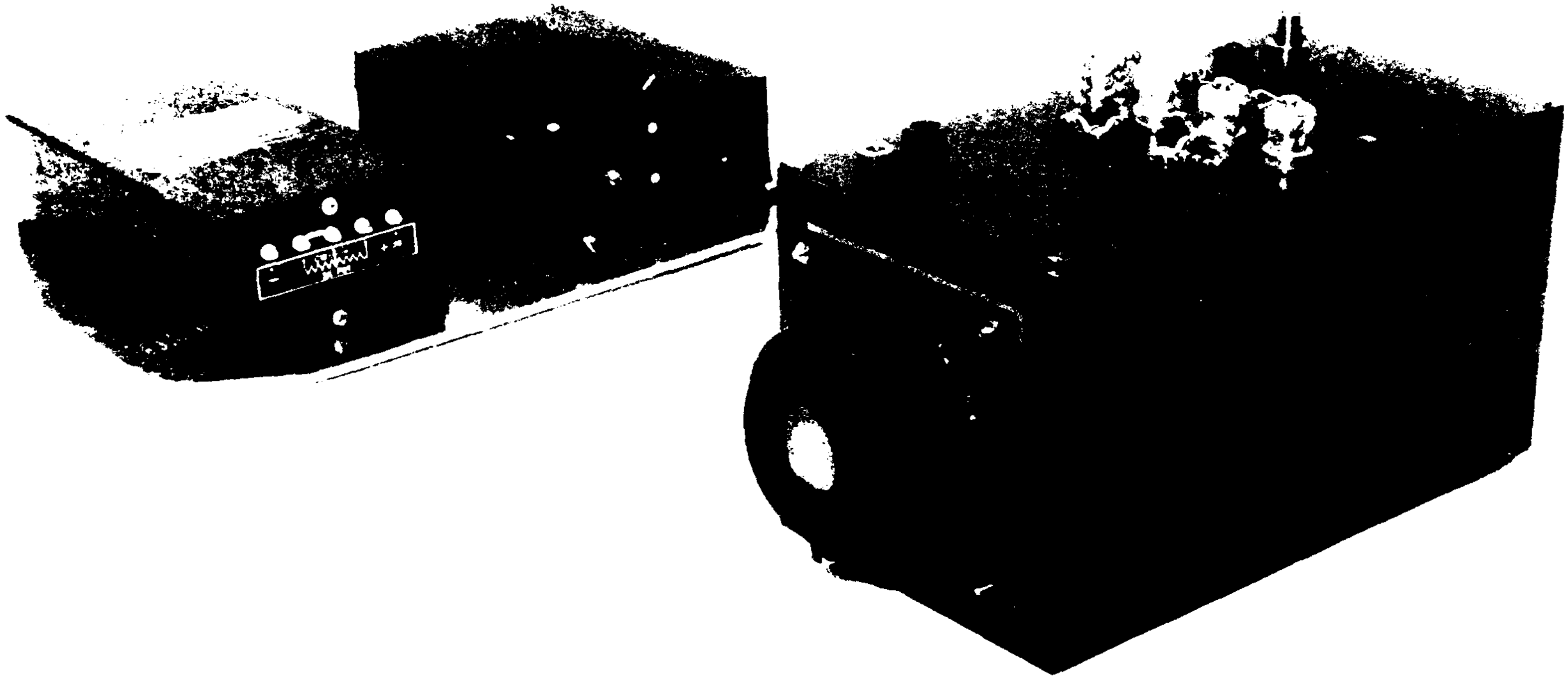


Figure 8

Breadboard UV Photon Detector System

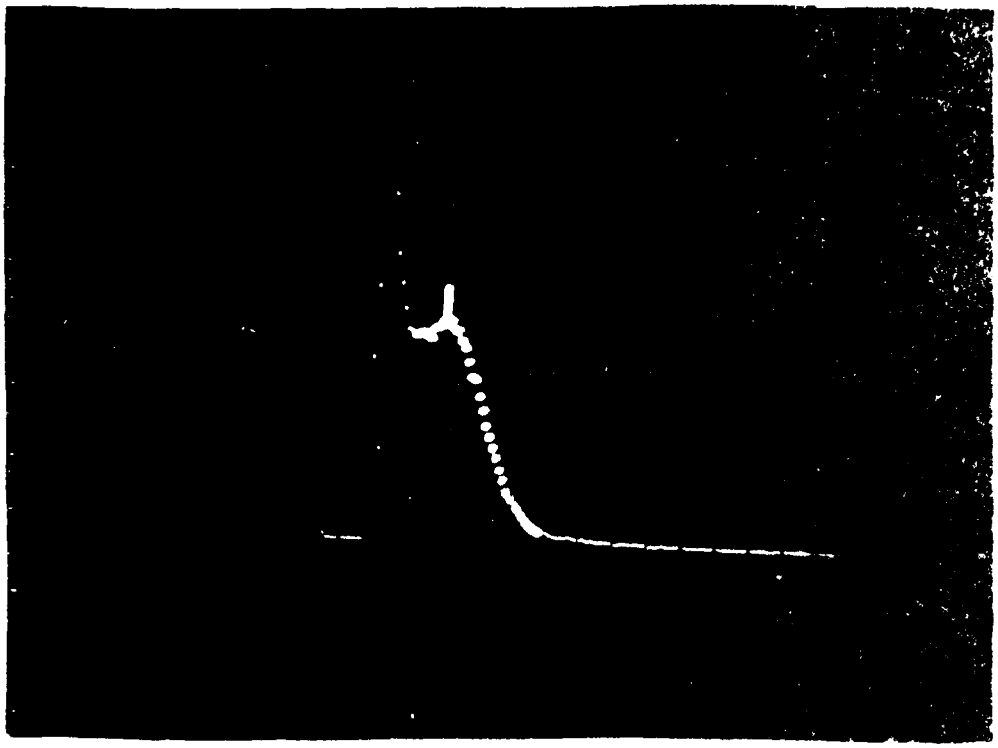
2.2 Test program

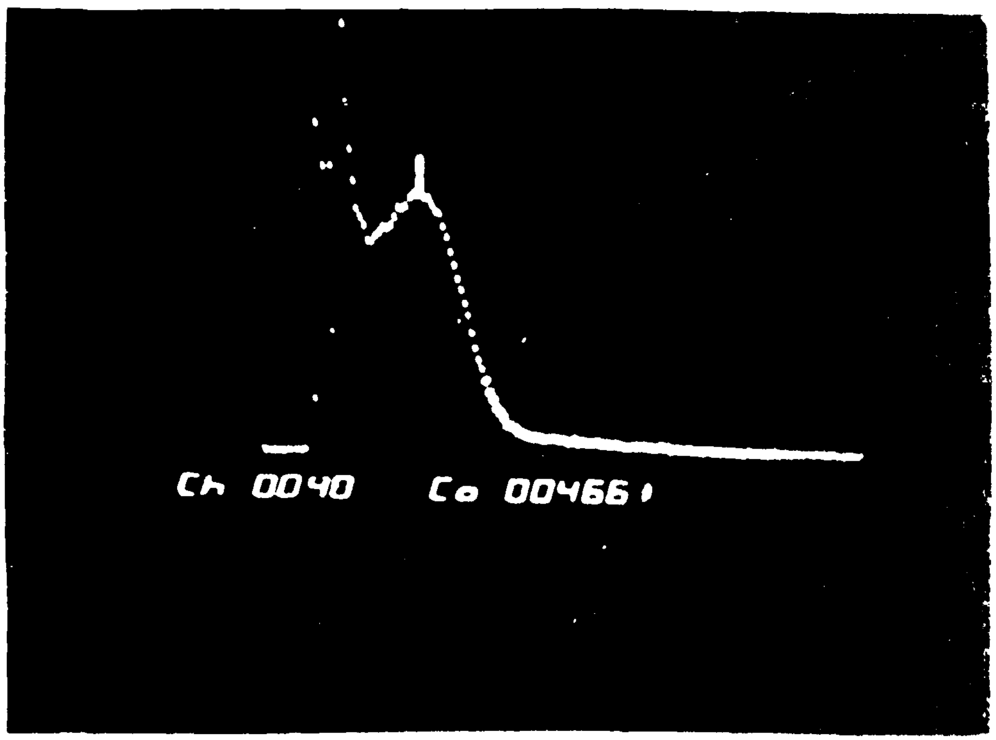
2.2.1 Detector tests

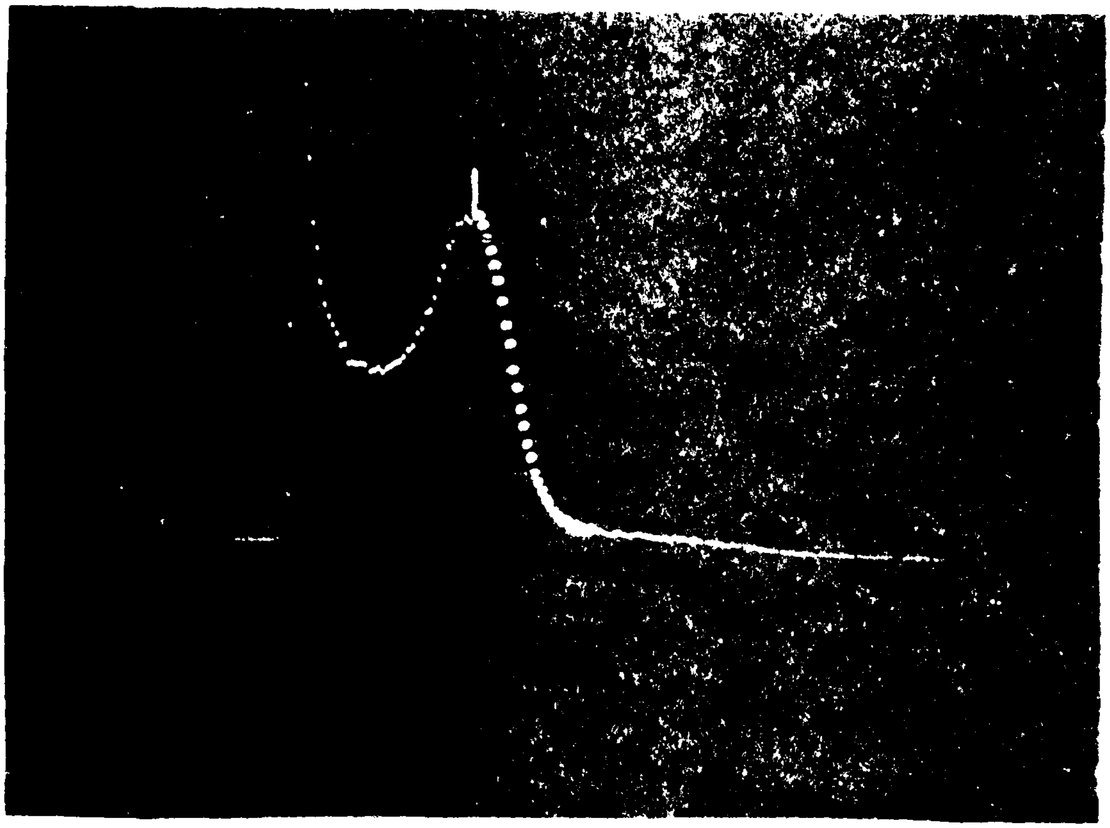
After fabrication the quadrant digicon was tested to determine its basic operational characteristics. A qualitative test of the photocathode produced satisfactory photocurrent measurements when illuminated by a pinhole mercury lamp.

The detector was then connected to a single channel amplifier, turned on and biased to 20 kV. We found the dark count to be very high ($>$ 1000 sec^{-1}) with pulse heights much larger than we had expected. The second quadrant digicon was tested similarly, producing similar results.

Since our primary objective was to get representative digicon performance data, we fabricated another digicon using a P on N diode array of the type previously used in the MSMP digicons. This tube was tested and performed as predicted producing $<$ 10 counts sec^{-1} $channel^{-1}$ dark count. We measured its pulse height distribution and found it to be as expected. The pulse peak varied with applied high voltage between 18 kV and 25 kV as shown in Figure 9 (a), (b), (c). (Notice that as the applied voltage was increased, the separation between signal pulses and amplifier noise increased.) The digicon was installed in the system and tested. In order to insure good signal-to-noise separation, the system discriminators were adjusted to place the low energy cut-off near the trough minimum.




Ch 0040
Co 00466



2.2.2 High voltage subsystem tests

The high voltage power supply is provided with a (variable) resistor-controlled voltage trimmer. Tests were made to determine the resistance vs. voltage relationship. The output of the high voltage power supply was connected to a 10,000:1 resistance divider (1×10^9 ohms). 1×10^5 ohms) and the voltage monitored as the control resistance was varied from 0 to 5×10^3 ohms. The results of these measurements are given in Table 1.

R(KΩ)	E (kV)
0	25.2
1	24.3
2	23.4
3	22.7
4	21.9
5	21.3

Table 1 Output Voltage as a Function of Control Resistance

2.2.3 Signal processing electronics subsystem tests

Tests were performed on the electronics to characterize performance prior to mating with the detector.

2.2.3.1 Noise

Measurements were made of the random amplifier noise for each channel of the system. Since the gain of the charge amplifier is a function of input capacitance, noise measurements were made with input capacitance at 18 pf and 28 pf, which brackets the capacitances expected from the detector. These data are shown in Table 2.

Input capacitance = 18 pf			Input capacitance = 28 pf		
CH	VRMS	mVp-p	CH	VRMS	mVp-p
1	.29	200	1	.33	300
2	.29	200	2	.32	300
3	.275	200	3	.29	300
4	.295	210	4	.33	320

Table 2. Variation of noise with input capacitance

2.2.3.2 Gain

The gain of the charge sensitive amplifiers was designed to be $V/q = 2 \times 10^{15}$, where q is the input charge in coulombs and V the output voltage. For measurements we inserted a charge of the approximate amplitude anticipated from the diode during normal operation.

$$q = 60\ \mathrm{uV}\ (28\ \mathrm{pf})$$
$$= 1.68 \times 10^{-15}\ \text{coulombs}$$

The output pulse heights were measured for each channel and gain calculated.

CH	V	G = V/q
1	1.85	1.1×10^{15}
2	1.88	1.1×10^{15}
3	1.7	1.01×10^{15}
4	1.8	1.07×10^{15}

2.2.3.3 Stability

During this test setup stability was monitored by varying pulse amplitude, rise time, and fall time to 10 times normal levels to try to induce ringing or oscillations. No tendencies toward instability appeared.

2.2.3.4 Count rate linearity

Measurements were made using a random pulse generator to vary the pulse rate input to the charge amplifier of each channel individually, and measuring the TTL output pulse rate.

Random Pulse Rate (Hz)	Ch 1 (Hz)	Ch 2 (Hz)	Ch 3 (Hz)	Ch 4 (Hz)
5335	6700*	5400*	5641*	5862*
10090	11100	10024	10200	11070
20360	20100	18950	19000	19500
29380	27800	27900	28100	27250
39550	35300	34900	34900	36100
50700	43600	42400	53500	43500
71600	59000	55600	57200	58200
101000	70600	65700	69700	70700

*noise form open front end varied from ~ 150 - 1500 Hz (different with each set up)

2.2.4 System tests

The Breadboard System Tests were performed as outlined in section 3.2 of the technical proposal.

2.2.4.1 Determination of digicon/electronics stabilization time (dark count)

The TTL output of the system was fed into a multichannel analyzer set to accumulate and record the pulses within 511 sequential 1 second integration periods. The analyzer was started and, about 10 seconds later, the detector system turned on: first low voltage (which produced no counts) then high voltage. Tests were run in a dark room. The results of this test are shown in Figure 10. As we expected, the dark count rate had reached a minimum of less than 10 counts/sec/channel by 120 seconds after turn-on. We were supprised to discover that following this minimum, the dark count increased throughout the remainder of the 511 second test period. A long term test was run monitoring the dark count for approximately 4.5 hours. The dark count continued to increase throughout this period and reached 150 counts/sec/channel the end of 267 minutes. We assume that this increase in dark count is caused by charge buildup and discharges from the detector and HV leads (which are not shielded and grounded in this breadboard configuration). Additional testing will be required to firmly determine the source of this noise and eliminate it.

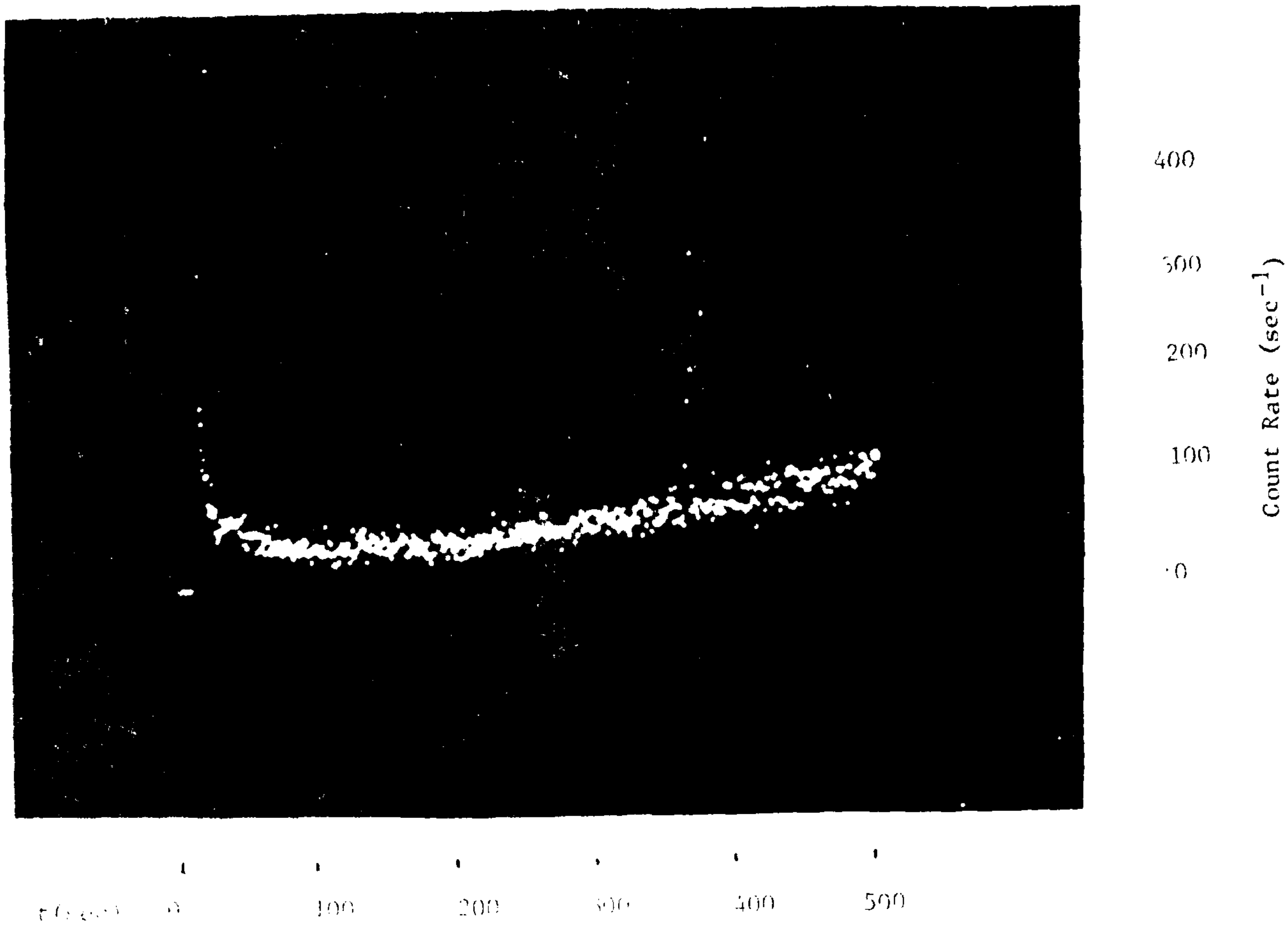
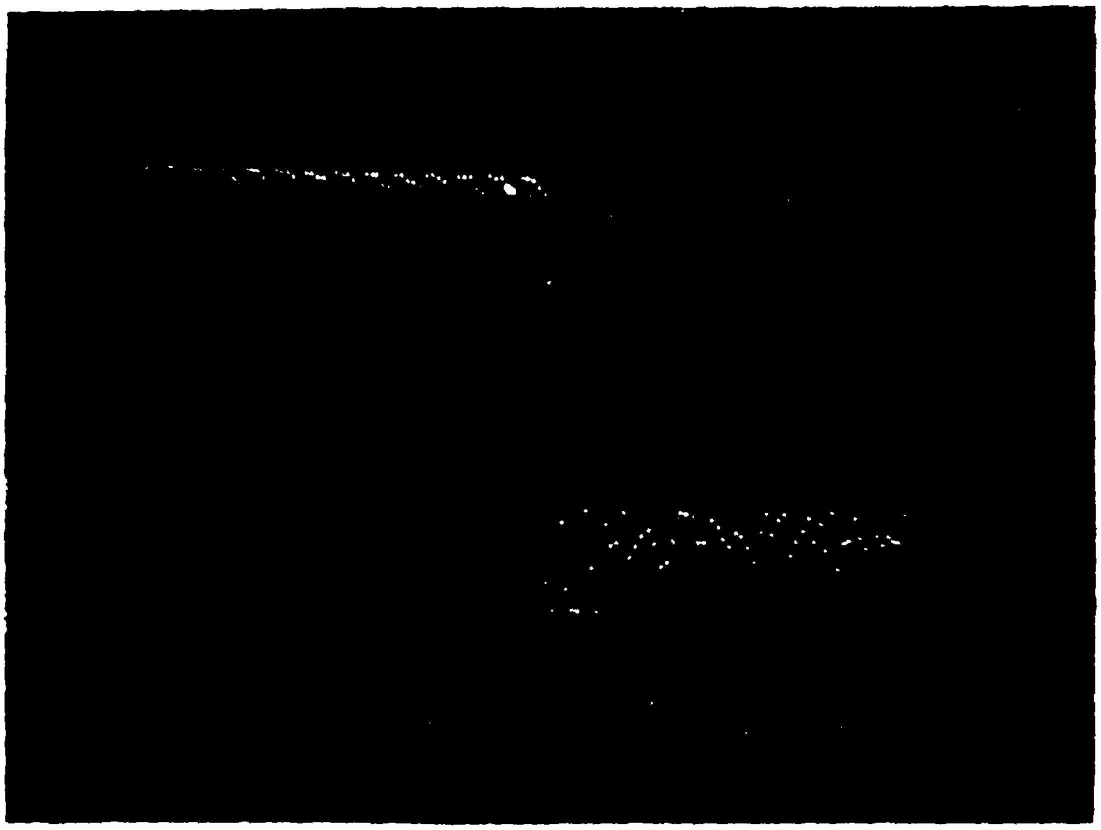


Figure 10

Digicon/Electronics Stabilization
Time After Initial Turn-on

2.2.4.2 Determination of recovery time of digicon/electronics following saturation from a high intensity UV light source

This test was performed using a shuttered high intensity UV source (Hg(A) lamp) to switch from high level illumination to weak UV illumination. The count rate from the TTL output was recorded on a Northern Multi Channel Analyzer sampling at 1 ms intervals. The high intensity lamp was adjusted to produce approximately 1.7×10^5 counts sec^{-1} and the low intensity rate around 300 counts sec^{-1}. The digicon system responded to the illumination as the high level source was shuttered off, reaching the low count rate in $T < .02$ seconds and stabilizing in $T < .1$ sec. (Figure 11). The variation in intensity with lamp on is the detector's response to the AC discharge lamp. The 120 Hz variation is clearly tracked when detector output is observed at high scan rates. The test was run again with a slower (10 ms intervals) MCS scan rate and with the high intensity lamp shuttered both on and off. Results showed the detector system completely stable in less than 0.3 sec following shuttering of the bright lamp.



Time(sec) 0 1 2 3 4 5

Figure 11

Digicon Recovery Time Following Saturation (10^{-2} sec/sample)

2.2.4.3 Determination of response/stabilization time of digicon/electronics to changes in UV light intensity

Two UV light sources were set up: one to produce near full count rates from the detector and the other to produce a low count rate. The output was monitored to determine response and stabilization times while the lamps were switched.

a. both off	e. both on
b. high only	f. low only
c. both on	g. both on
d. high only	h. both off

Measurements were made with the multichannel scanner integrating for 0.1 second per channel and the count rates approximately

both off 750 counts/sec (background light)

low only 4000 counts/sec

High only 20,000 counts/sec

The responses measured showed response/stabilization times to be (Figure 12).

a to b .3 sec

b to c .2 sec

c to d .2 sec

d to e .2 sec

e to f .2 sec

f to g .4 sec

g to h .2 sec

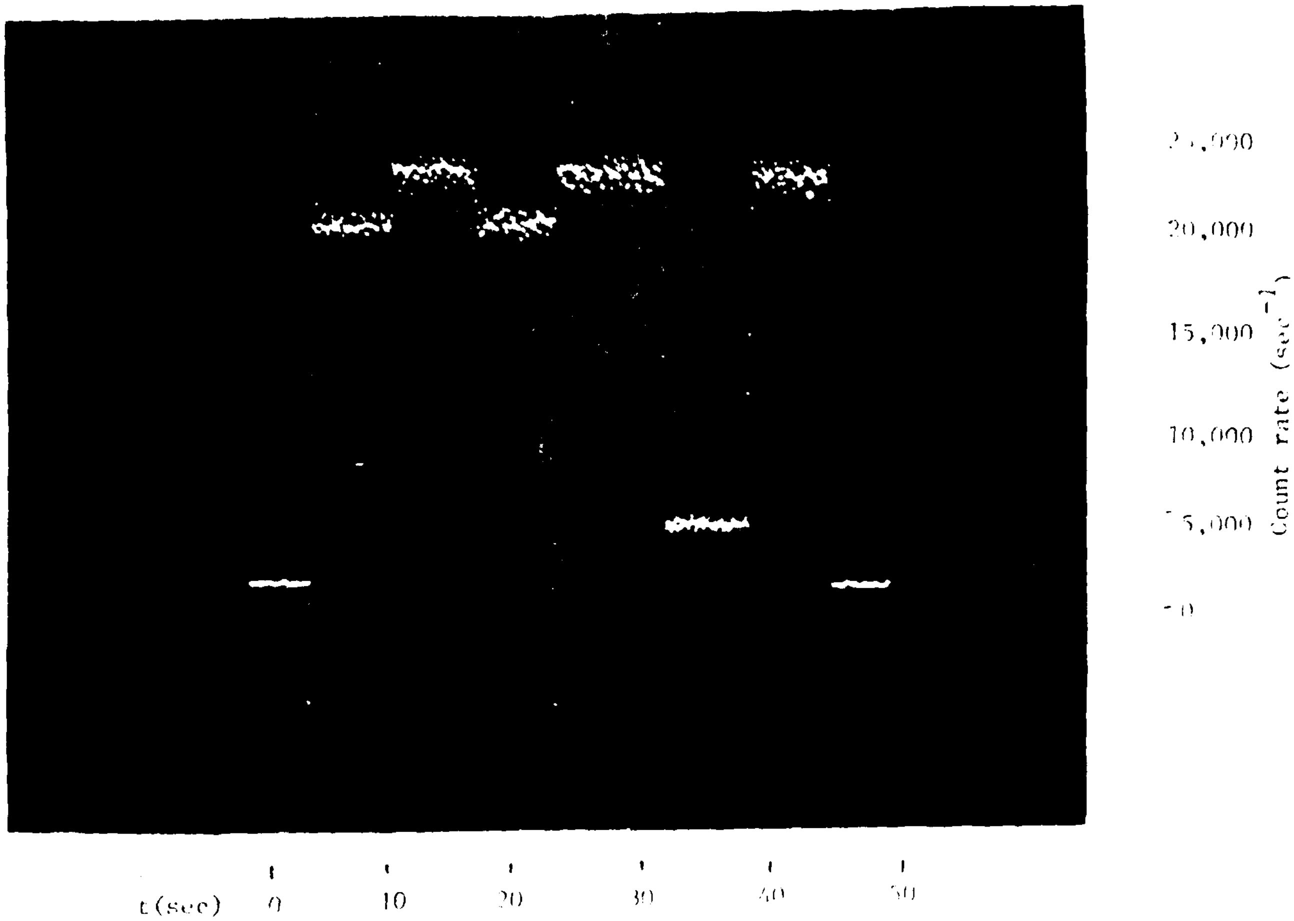


Figure 1[illegible]

Response/Stabilization Time
Changes in UV Intensity (10^{-1} sec/sample)

2.2.4.4 Determination of the system's sensitivity to variations in the high voltage source

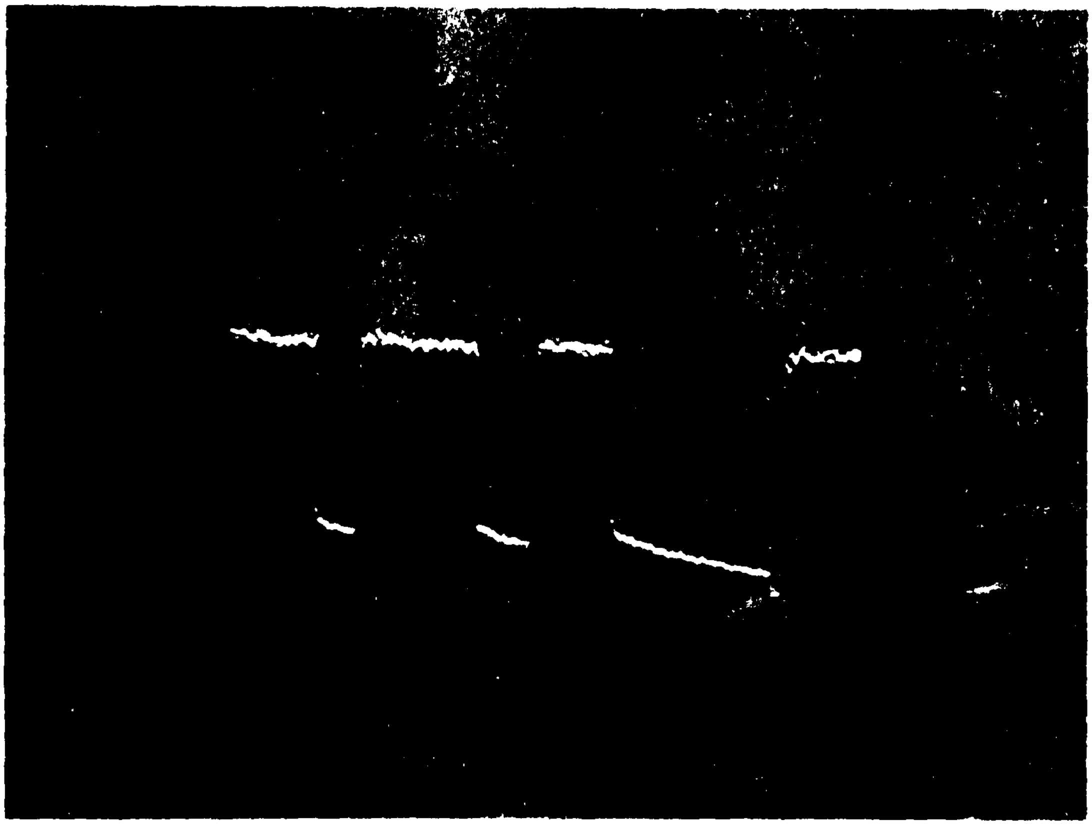
Count rates were monitored at three levels of light intensity while high voltage was varied by changing the bias resistor between its limits of 5kΩ to 0Ω. The output voltage relates to resistor voltage as shown in section 2.2.2. Results of these tests are given in Table 3.

Resistance(KΩ)	0	1	2	3	4	5
High Voltage (kV)	25.2	24.3	23.4	22.7	21.9	21.3
High level output (sec^{-1})	$2.5x10^4$	$2.3x10^4$	$2.2x10^4$	$1.9x10^4$	$1.7x10^4$	$1.5x10^4$
Medium Level output (sec^{-1})	$6.4x10^3$	$5.4x10^3$	$4.4x10^3$	$3.6x10^3$	$3.0x10^3$	$2.7x10^3$
Low level output (sec^{-1})	2800	2000	1400	900	650	550

Table 3 Variation of Digicon System Count Rate to changes in High Voltage.

2.2.[illegible] Determination of short [illegible] ... [illegible]

This test was performed by [illegible] the [illegible] for [illegible] a moderate intensity source [illegible] sec^{-1}) [illegible] the [illegible] while the high voltage [illegible] repeated [illegible] channel analyzer was [illegible] voltage was turned off [illegible] on for 6 seconds, [illegible] system had recovered [illegible] within [illegible] (Figure [illegible] 3).



[illegible] (sec) [illegible]

2.2.4.6 Determination of short term stability following light transients

This test was performed by operating the breadboard detector system viewing a moderate intensity source (~ 35,000 sec^{-1}) and superimposing a bright source (~ 500,000 sec^{-1}) of short duration. The recovery time was monitored using the multichannel analyzer set at [illegible] sec integration time. The system was pulsed with the bright light transient for approximately one second three times and allowed to settle for about [illegible] seconds between transients. We found the system to have recovered and stabilized within .3 seconds in each case. (Figure 15)

Fig. [illegible]

3. CONCLUSIONS

The digicon-based Breadboard Photon Detection System has been shown to be a very highly responsive system for the measurement of low levels of ultraviolet radiation. In all cases tested, the system responded to and recovered from both minor and extreme changes in incident UV light levels very rapidly (worse case less than 400 ms). Similar times were measured for the recovery from both light and high voltage transients. The system's settling/stabilization time following initial turn-on was found to be less than 60 seconds.

In only one area the system tests gave results less than desired: that relating to noise. We found that after initial settling of the detector, the background count increased with time from less than 10 counts sec^{-1} $channel^{-1}$ to around 100 counts sec^{-1} $channel^{-1}$ at 2500 sec ($\sim$ 40 min) to around 150 counts sec^{-1} $channel^{-1}$ at 16000 sec ($\sim$ 4.5 hours). This problem was also exhibited in the high voltage stability test (section 2.4.4.4) since due to this noise the discriminator levels were moved closer to the pulse peak than optimum, causing the system to be more sensitive to changes in high voltage than it would have been with more optimized settings. We assume that this increase in background noise is caused by charge buildup and leakage and that it can be eliminated by improved grounding and shielding in the detector and high voltage cables.

4. RECOMMENDATIONS

It has been shown that a UV photon detection system using a digicon type photon detector potentially offers many advantages over conventional UV detectors (pm tubes)for application in passive UV threat warning systems.

We recommend that the program which began with this breadboard sensor evaluation be continued through the development of a flyable prototype sensor to permit flight evaluation of the digicon detector in this configuration. This will require some additional investigation into the source of background noise and the elimination of this problem. Additionally it will require repackaging of the data handling electronics and high voltage supply.

5. REFERENCES

Russak, S. L. et al. in proceedings of The Seventh Symposium on Photo-Electric Image Devices, Blackett Laboratories Imperial College (1978).

DISTRIBUTION LIST

Commander 1
Hanscom AFB
ATTN: AFGL/LKO (Dr. R. E. Huffman)
Massachusetts 01731

Commander 1
Naval Weapons Center
ATTN: W.R. McBride, Code 3854
China Lake, CA 93555

Commander 1
Pacific Missile Test Center
ATTN: D. E. Papcke, Code 1233
Point Mugu, CA 93042

Commander 1
Naval Research Laboratory
ATTN: R. A. Patten, Code 5530
Washington, D.C. 20375

Mr. David M. Reilly 1
Honeywell Electro-Optics Center
2 Forbes Road
Lexington, MA 02173

Dr. M. Rome 1
EMR Photoelectric
Box 44
Princeton, N.J. 08540

Prof. W. E. Spicer 1
Stanford Electronic Laboratories
McCullough Bldg 228
Stanford, CA 94305

Commander 1
Naval Air Systems Command
ATTN: W. K. Whiting AIR 53322C
Washington, D.C. 20361

Director, Electronic Warfare Laboratory
ERADCOM
ATTN: DELEW-E(J. Charlton) 6
DELEW-P(E. Newsom 1
Ft. Monmouth, N.J. 07703

Dr. Jar Mo Chen Martin Marietta Laboratories 1450 S. Rolling Road Baltimore, MD 21227	1
Defense Documentation Ctr. ATTN: DDC-TCA Cameron Station, Bldg 5 Alexandria, VA 22314	12
Office of Naval Research Code 427 Arlington, VA 22217	1
Director Naval Research Laboratory ATTN: Code 2627 Washington, D.C. 20375	1
Commander Naval Electronics Lab Ctr ATTN: Library San Diego, CA 92152	1
Rome Air Development Center ATTN: Documents Library (TILD) Griffis AFB, N.Y. 13441	1
Commander Redstone Scientific Info Ctr ATTN: Chief, Document Section Redstone Arsenal, AL 35809	1
HQDA (DAMA-ARZ-D) ATTN: Dr. F. C. Verderame Washington, D.C. 20310	1
Cdr, Harry Diamonds Labs ATTN: Library 2800 Powder Mill Road Adelphi, MD 20783	1
Commander, TARADCOM ATTN: DRDTA-UL, Tech Library Warren, MI 48090	1
Chief, Ofc. of Missile EW Electronic Warfare Lab, ERADCOM White Sands Missile Range, N.M. 88002	1
NASA Scientific & Tech Info Facility Baltimore/Washington Int'l Airport P.O. Box 8757 Baltimore, MD 21240	1

Advisory Group on Electron Devices
201 Varick Street, 9th Floor
New York, N.Y. 10014

1